- For frequencies greater than fc, the circuit strongly attenuates the amplitude. Thus, when the source frequency is in this range, the circuit's output has a much smaller amplitude than that of the source.

For these reasons, this frequency is known as the **cutoff frequency**. In this circuit the cutoff frequency depends only on the product of the resistance and the capacitance. Thus, a cutoff frequency of 1 kHz occurs when

$$\frac{1}{2\pi RC} = 10^3$$

or

$$RC = \frac{10^{-3}}{2\pi} = 1.59 \times 10^{-4}$$

. Thus resistance-capacitance combinations of 1.59 kΩ and 100nF or 10 Ω and 1.59 μF result in the **same** cutoff frequency.

The phase shift caused by the circuit at the cutoff frequency precisely equals

$$-\left(\frac{\pi}{4}\right).$$

Thus, below the cutoff frequency, phase is little affected, but at higher frequencies, the phase shift caused by the circuit becomes

$$-\left(\frac{\pi}{2}\right).$$

This phase shift corresponds to the difference between a cosine and a sine.

We can use the transfer function to find the output when the input voltage is a sinusoid for two reasons. First of all, a sinusoid is the sum of two complex exponentials, each having a frequency equal to the negative of the other. Secondly, because the circuit is linear, superposition applies. If the source is a sine wave, we know that

$$\begin{aligned} v_{in}(t) &= Asin(2\pi ft) \\ &= \frac{A}{2j}(e^{j2\pi ft} - e^{-(j2\pi ft)}) \end{aligned}$$

Since the input is the sum of two complex exponentials, we know that the output is also a sum of two similar complex exponentials, the only difference being that the complex amplitude of each is multiplied by the transfer function evaluated at each exponential's frequency.

$$v_{out}(t) = \frac{A}{2j}H(f)e^{j2\pi ft} - \frac{A}{2j}H(-f)e^{2(je\pi ft)}$$

As noted earlier, the transfer function is most conveniently expressed in polar form: $H(f)=|H(f)|e^{j\angle(H(f)}$. Furthermore, $|H(-f)| = |H(f)|$ (even symmetry of the magnitude) and $\angle(H(-f)) = -(\angle(H(f))$ (odd symmetry of the phase). The output voltage expression simplifes to

$$\begin{aligned} v_{out}(t) &= \frac{a}{2j}|H(f)|e^{j2\pi ft+\angle(H(f))} - \frac{A}{2j}|H(f)|e^{-(j2\pi ft)-\angle(H(f))} \\ &= A|H(f)|sin(2\pi ft + \angle(H(f)) \end{aligned}$$